Draft Nutrient Budget for Nueces Bay

Presented by

Dan Opdyke, Ph.D., P.E.

May 1, 2017

Outline

- Conceptual site model (CSM)

- Quantification of nitrogen sources and sinks
  - Pre- and post-development (pre- and post-1986)

- Investigation of paleoecological reconstruction for assessing pre-development conditions

- Next steps

Notes:
This presentation should be considered a progress report.
A written draft report will be submitted by June 30, 2017.

Conceptual Site Model

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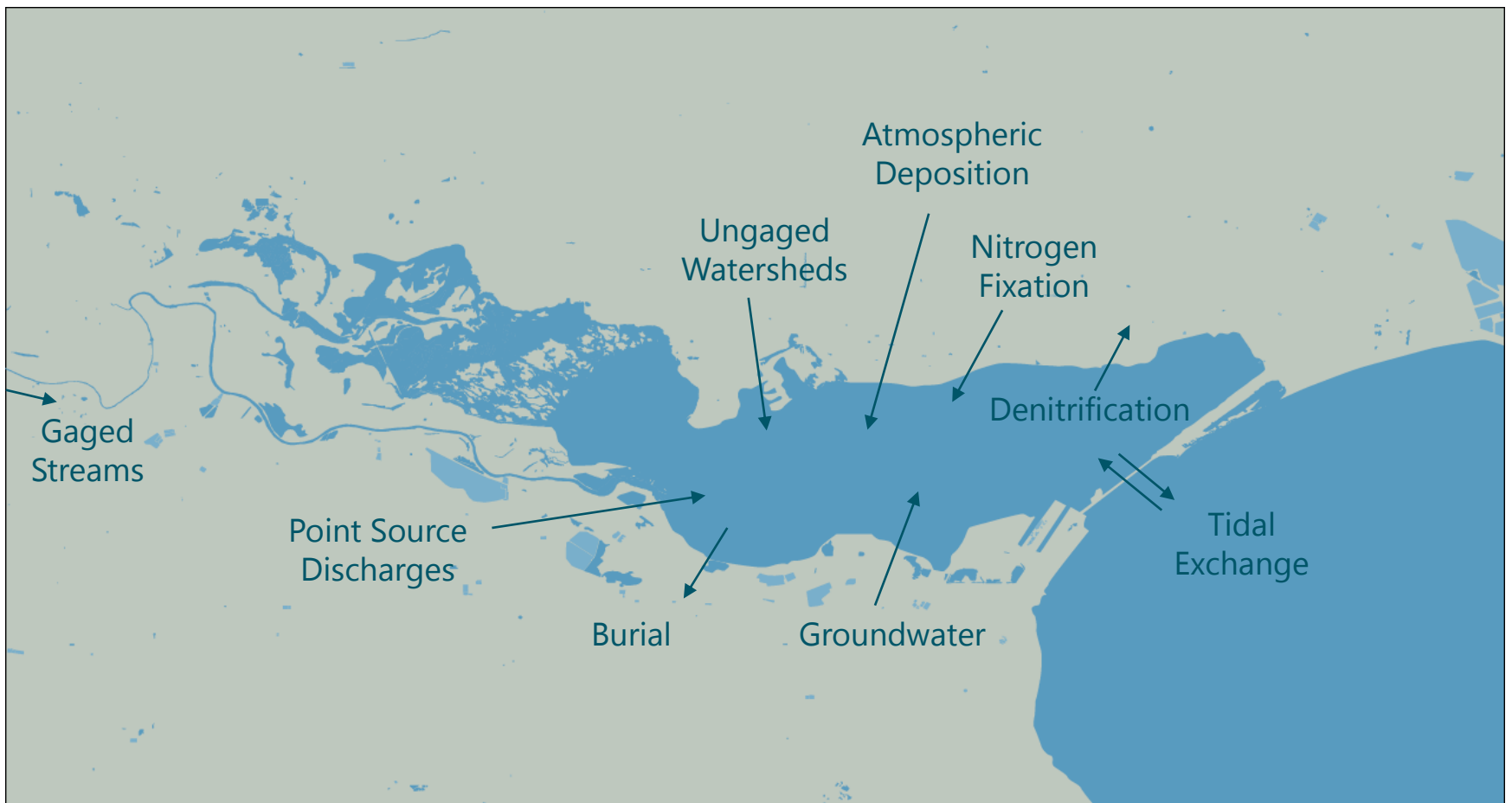
Framework for understanding and prioritizing nutrient sources and sinks for a waterbody

Conceptual Site Model Development

Determination of Limiting Nutrient

- Primary productivity (e.g., algal growth) in Nueces Bay is predominantly limited by nitrogen (N), not phosphorus (P)
  - Low N:P ratios in water
    - Rincon Bayou: USBR 2000
    - Nueces Bay: calculated ratios using bay data in BBEST 2011
  - Laboratory bioassays
    - Enhanced algal growth following addition of N (USBR 2000)
  - This observation is typical for estuaries

Focus of nutrient budget is total nitrogen (TN)

Quantification of Nitrogen Sources and Sinks

Sources:

Gaged streams

Ungaged watersheds

Wastewater treatment plants
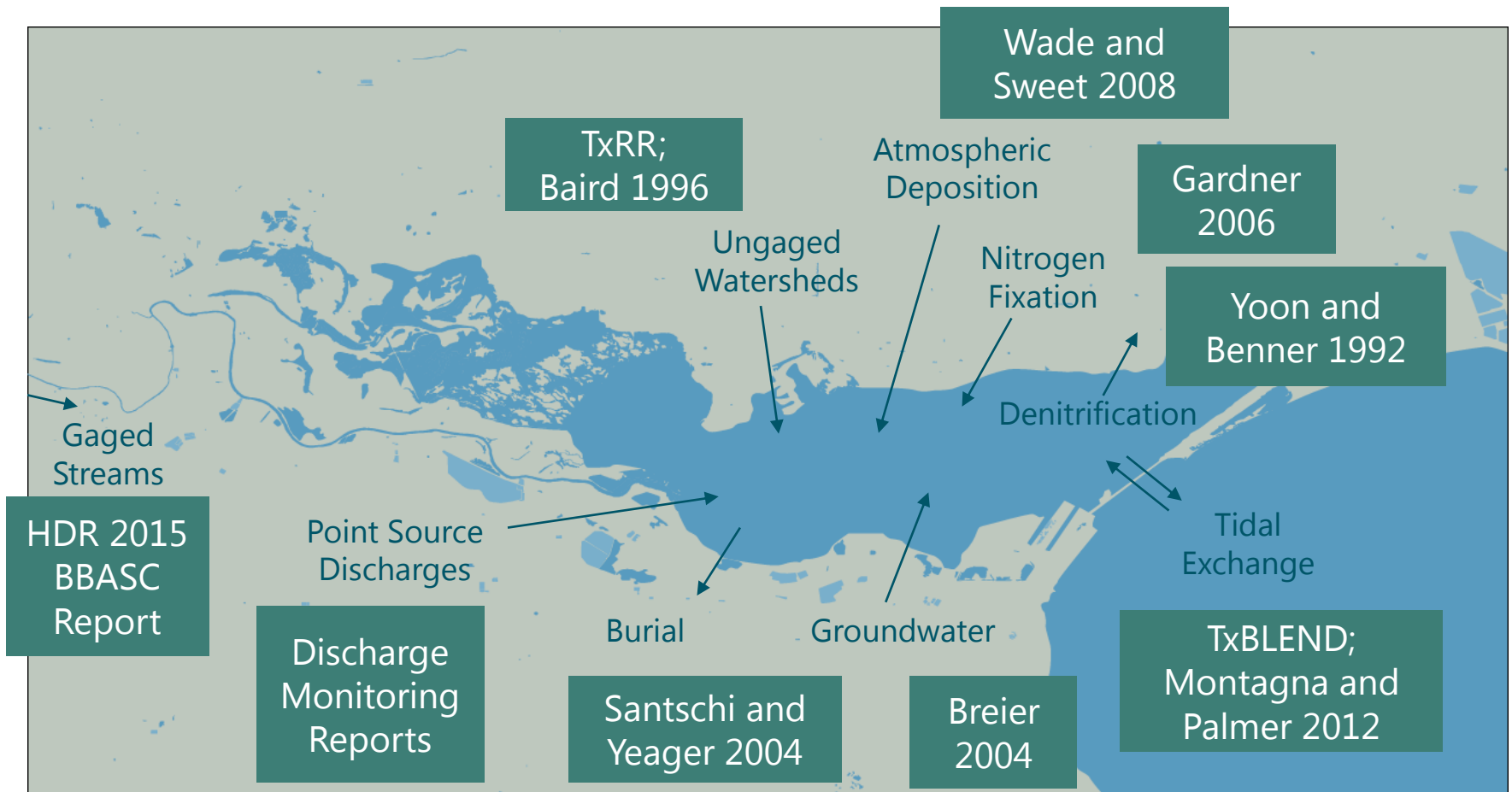
Wet and dry deposition

Nitrogen fixation

Groundwater

Sinks:
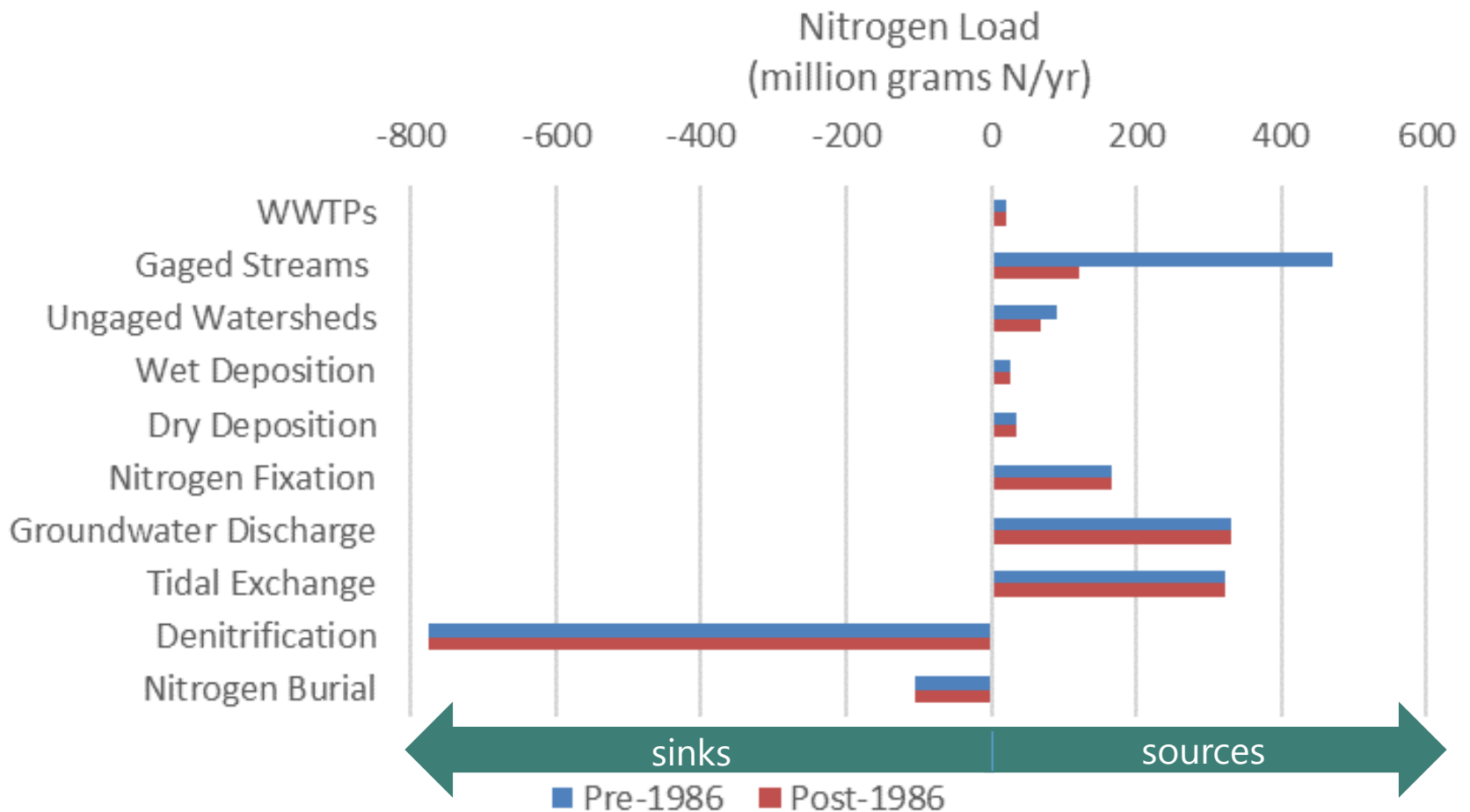
Denitrification

Burial

Source or Sink:

Tidal exchange

Nitrogen Quantification

- For each CSM component, estimate TN loading rate (mass N per year) under average flow conditions

- Where possible, estimate pre-development (pre-1986) and post-development (post-1986) TN loadings

Primary Sources for Quantifying Loads

Note: Several budget terms do not have discrete data for pre-1986 and post-1986 and are shown with equal values

Preliminary Summary of Nitrogen Budget

Paleoecological Reconstruction for Assessing Pre-development Conditions

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Sound Ecological Environment

- Senate Bill 3 environmental flow regime[1]

    "A schedule of flow quantities that ... support a sound ecological environment"

    "The BBEST agrees that the sound ecological environment ... depends on ... [the waterbody's] historical conditions"

    "... the BBEST reached consensus that the Nueces Bay and Delta region is an unsound ecological environment."

To inform what a sound ecological environment might be, we can evaluate historical (1800s) conditions.
One way this can be done is to look for residues in sediment cores that indicate historical conditions.

[1] All quotes are from the BBEST report

# Step 1: Obtain sediment sample(s) from 1700s – 1800s

- Age of sediment can be informed by measuring
  - Radioisotopes and elemental tracers
  - Pollen residues
  - Fertilizer residues
  - Sediment layers indicating upland erosion or storm deposits

- Reconstruction of recent history not needed; recent disturbances in system are not barrier to evaluation
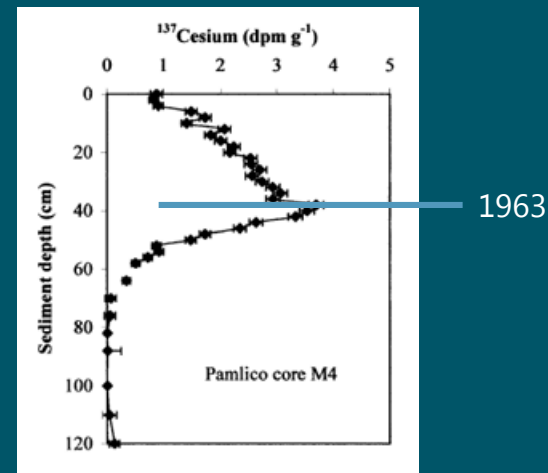
1963

Cesium-137 Profile (1963 Peak at 40 cm)
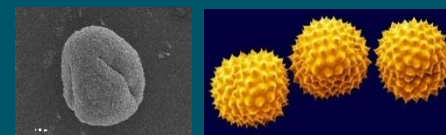
Oak and Ragweed Pollen
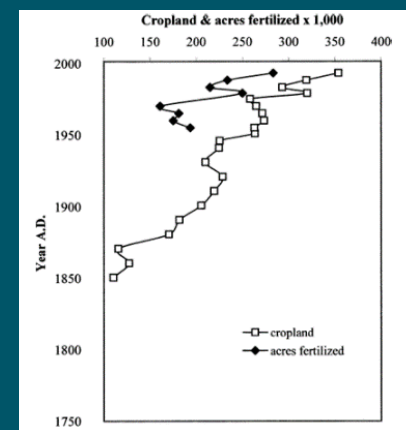
Agriculture

Step 2: Evaluate Ecosystem Indicators

- Certain residues can be examined and correlated to ecosystem characteristics

- Algae (diatom) taxonomic shifts
  - Diatom cell walls made of silica and well preserved in sediment
  - Species have different shapes
  - Less turbid, low nutrient water favors benthic and epiphytic diatoms
  - Higher turbidity and nutrients favor pelagic diatoms

- Organic biomarkers (pigments, lipids, and lignin)
  - Markers indicate upland (terrestrial) vs. estuarine algal (plankton) production
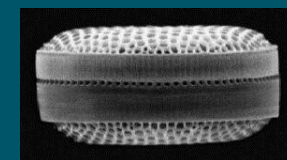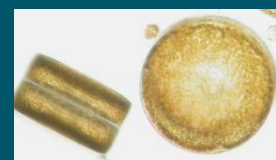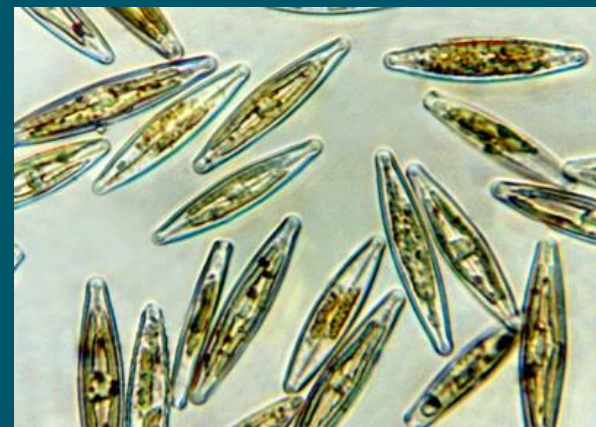
Diatom Images
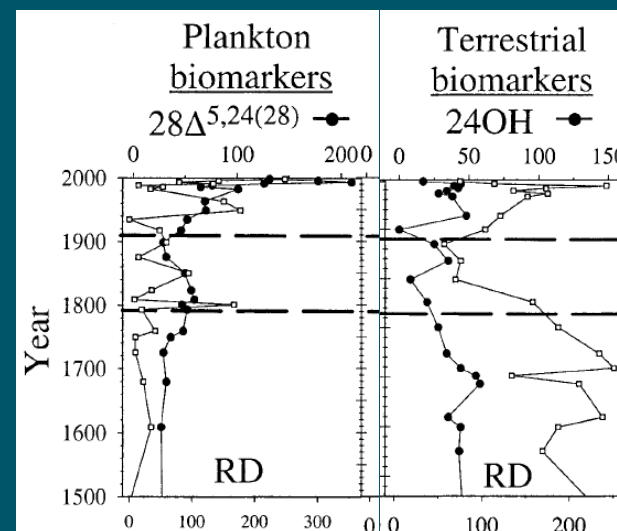
Goals of the Paleoecological Effort

- Literature review and discussions with researchers in progress
  - Mark Besonen, Philippe Tissot, and Erin Hill, TAMUCC

- Anchor QEA is not tasked with undertaking paleoecological study

- Instead, we will summarize the literature and provide recommendation for whether such a study may be helpful to BBASC/NEAC in the future

Remaining Work

Remaining Work

- Review macro-detritus literature

- Finalize N budget numbers
  - Estimate uncertainty where possible

- Complete paleoecological review

- Draft conclusions and recommendations

- Deliverables
  - June 30: draft report
  - July 31: comments from NEAC/BBASC due
  - August 31: final report

Questions/Discussion

Backup Slides

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Gaged Streams (Nueces River at Mathis)

- Nueces River N load

  Load = Flow × TN Concentration

- Data sources: linear regression analysis of measured flow and nutrient concentrations

- Pre-1986: HDR 2015 BBASC Report

  - Pre-1986 load provided by HDR at Three Rivers, but not at Mathis

  - Assume pre-1986 percent change in load between Three Rivers and Mathis stations is same as for post-1986

  - Apply this percent change to HDR-estimated post-1986 load at Three Rivers

- Post-1986: HDR 2015 BBASC Report

Ungaged Watersheds

- Ungaged watersheds load

> Load = Flow × TN Concentration

- Pre-1986
  - Flow: average of TxRR modeled flows from 1941 to 1986
  - Concentration: same as post-1986

- Post-1986
  - Flow: average of TxRR modeled flows from 1987 to 2015
  - Concentration: estimated based on land use types
    - Runoff concentration by land use type for Coastal Bend area (Baird et al. 1996)
    - Land-use: National Land Cover Database 2011

Wastewater Treatment Plants

- WWTP load

  Load = Flow × TN Concentration

- Two main WWTPs: Allison and City of Portland

- Pre-1986

  – Flow: Pacheco (1990) reports 1987 flows

  – Concentration: based on communication with Allison WWTP operator, assume same concentration as Post-1986

- Post-1986

  – Flow: Discharge Monitoring Reports (DMRs) from 2002 – 2016

  – Concentration

    • Allison: estimate from DMR data (1995 – 2013)

    • City of Portland: no data available (assume same as Allison)

Wet and Dry Deposition

- Wet Deposition

  Load = Rainfall × TN Concentration × Surface Area

- Dry Deposition

  Load = Particulate Settling Velocity × TN Concentration × Surface Area

- Pre-1986: same as post-1986

- Post-1986

  - Inorganic N load per area: average of 1998 results from Whites Point station (Wade and Sweet 2008)

  - Scaled to TN by assuming 19% organic N composition (Ockerman and Livingston 1999)

Nitrogen Fixation

- Conversion of atmospheric N to cellular N by blue-green algae (cyanobacteria)

> Load = Fixation Rate Per Area × Surface Area

- Pre-1986: same as post-1986

- Post-1986
  - Rate per area: average of seasonal rates from 2001 – 2003 from sites in Nueces Bay and Corpus Christi Bay (Gardner et al. 2006)

Groundwater Discharge

- Transport of dissolved N into waterbody via subsurface flow

  Load = Flow × TN Concentration

- Pre-1986: same as post-1986

- Post-1986

  - Nitrate load: directly from Breier et al. 2004 (mid-point of range)

  - Currently working on adjusting nitrate load to TN

- Dr. Dorina Murgulet (TAMUCC) recently investigated groundwater nutrient fluxes in Nueces Bay

  - Draft publication anticipated in summer 2017

Tidal Exchange with Corpus Christi Bay

$$\text{Load} = \text{Entrained Tidal Volume} \times \text{Difference in TN Concentration between Nueces Bay and Corpus Christi Bay}$$

- Pre-1986: same as post-1986

- Post-1986
  - Tidal volume from TxBLEND hydrodynamic model
  - Estimation of water entrainment rate
    - Iteratively applied a salt-balance calculation using TxBLEND model inputs and outputs
  - Concentration: average TKN + average NOx from ~1970 – 2010 (Montagna and Palmer 2012)

Denitrification

- Conversion of nitrate to gaseous N, which then exits waterbody

- Typically performed by bacteria under very low oxygen conditions (e.g., in sediments)

> Load = Denitrification Rate Per Area × Surface Area

- Pre-1986: same as post-1986

- Post-1986

  – Rate per area: average of seasonal values from 1988 and 1989 from two stations in Nueces Bay (Yoon and Benner 1992)

Nitrogen Burial

- Deposition on sediment bed buries underlying N mass, thereby making N no longer accessible for uptake by algae and plants

Load = Sedimentation Rate × N Content at 10 cm Depth × Surface Area

- Pre-1986: same as post-1986

- Post-1986
  - Rate of deposition: average from Nueces Bay sites (Santschi and Yeager 2004)
  - Sediment density: Hill et al. 2014
  - N content of sediment at 10 cm: Brock 2001
    - › Currently looking for additional data sources
  - Assumes 10 cm depth active layer